IN THE UNITED STATES PATENT AND TRADEMARK OFFICE
BEFORE THE BOARD OF PATENT APPEALS AND INTERFERENCES

In re patent application of:

Bertram SUGG | Before the Board of Appeals

Serial No. 10/540,026 | Art Unit: 2837

Filed: January 25, 2006 | Examiner: B. Gordon

For: PIEZOELECTRIC ACTUATOR AND A METHOD FOR ITS MANUFACTURE

Date: March 22, 2010

APPELLANT'S REPLY BRIEF (37 CFR 41.41)

Commissioner for Patents
P.O. Box 1450
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Sir:

This Reply Brief is filed in response to the Examiner's Answer mailed on January 20, 2010:

The rejection of claims 9-10, 13-14 and 29-32 under 35 U.S.C. 102(b)
as anticipated by Schreiner et al. (PG Pub. 20020175591).

On page 7 of the Examiner's Answer, particularly in the sentence which spans lines 8-9, the examiner has made it clear that he believes the sintered layer of Schreiner et al. coats the entire stack, including the inner electrodes, with the sintered skin. The examiner quotes Schreiner et al. from lines 4-5 of paragraph 23, where Schreiner et al., in talking about figure 3 state "It has a circular cross-section 12 and is **fully** coated by a sinter skin 17." The examiner has apparently jumped on this statement and taken it to mean that the entire piezoelectric stack has a coating and is thus insulated.

But the quoted sentence is **neither** an accurate, nor a full description of the actual structure of Schreiner et al. It is only an approximation. In fact, if the entire disclosure of Schreiner et al. is considered closely, this statement turns out to be in conflict with the remainder of Schreiner et al.

Schreiner et al. disclose in paragraph 21 that the multilayer actuators, still in the green state, get a final machining, which machining places them in their final diameter and/or shape. Just as applicants have argued all along, such machining will expose the edges of the inner electrodes, it they were not already exposed, and they will remain exposed. The inner electrodes are exposed not only where the outer electrodes are to be connected, but also around the entire periphery of the actuator, just as shown in figure 3. Figure 3 shows that every inner electrode extends completely to the edge of the actuator and is exposed around the periphery of the multilayer actuator, except for where alternating layers are purposefully stopped short from contacting the outer electrodes.

As disclosed in the specification of Schreiner et al. and as shown in figure 3, the multilayer actuator has edges of inner electrodes 11 exposed at the periphery of the multilayer actuator. The edges of the inner electrodes are exposed, either by their formation or by the machining which Schreiner et al. disclose, and these edges will remain exposed since there is no piezoelectric material covering them. The sintering process which Schreiner et al. perform later does not somehow cause the piezoelectric material of Schreiner et al. to magically cover the exposed edges of the inner electrodes. The inner electrodes of Schreiner et al. will not have any sintered material, and no insulation covering them. The edges of the inner electrodes of Schreiner et al. are left exposed.

In paragraph 7 Schreiner et al. specifically state that "... even in the region where the internal electrodes emerge at the surface of the actuator, that subsequent insulation of the surfaces of the piezoelectric multilayer actuator **can usually be omitted.**" Thus more often than not there is no insulation covering the edges of the inner electrodes. And in the few instances where an insulation layer might be added, Schreiner et al. does not disclose what this insulation layer should be made from, and certainly does not disclose that it should be made from a slurry of the piezoelectric material. And again, for most instances, according to the language of Schreiner et al., the inner electrodes will remain exposed and not be covered with any insulation. Clearly the reference to Schreiner et al. does not teach coating the inner electrodes with the ceramic material which is used to form the piezoelectric layers.

Thus clearly the structure disclosed by Schreiner et al. is not the same as recited in applicants' claims, since Schreiner et al. do not teach coating, nor in any way any details whatsoever of insulating the edges of their inner electrodes.

In opposition to this, claim 9 recites "... the regions between the outer electrodes being provided with an insulation layer, comprised of the same ceramic material as the piezoelectric layers themselves, and the insulating layer being applied to the outer surface of the piezoelectric **actuator** in the green state of the piezoelectric actuator before sintering." Since claim 9 recites that the **actuator** is coated with the ceramic piezoelectric material, this includes that the inner electrodes are coated. As explained above, this is not the situation in Schreiner et al.

Claims 10, 13 and 14 each go on to recite even further details which still further insure that the edges of the inner electrodes are covered by the insulating layer.

And claim 29 recites the product-by-process apparatus " .... coating the outside of the piezoelectric **stack** with a layer of material which is the same material as the piezoelectric layers." In other words, the entire piezoelectric **stack**, and this includes that all of the inner electrodes plus the piezoelectric layers are coated with the same material as is used as the piezoelectric material. This gives a coating to the edges of the inner electrodes. As pointed out above, this is different from the structure of Schreiner et al., because in Schreiner et al. the edges of the inner electrodes have no such coating. Clearly the claimed structure is not the same as that of Schreiner et al., and is not obvious in view of Schreiner et al.

Furthermore, claims 31-32 each go on to recite even further details, which further details still further insure that the edges of the inner electrodes are covered by the insulating layer.

Thus Schreiner et al. cannot be said to anticipate either of claims 9 or 29, nor any of the claims which depend on those claims. Nor can the structure of Schreiner et al. be said to make the details of these claims obvious. Since Schreiner et al. do not teach the claimed details, there is not teaching which makes these details obvious.

With Regard to the Examiner's Advisory Action of February 18, 2010, which states that in Section 8, Evidence Relied Upon, Schreiner et al. should have been listed

The patent rules, in particular 37 CFR 1.41.37(c) (viii) and (ix), seem to clearly indicate that appendix (viii) should include copies of the claims, and that the evidence requested as appendix (ix) is intended to be evidence such as submitted under sections 1.130, 1.131, or 1.132, not the references relied on for the rejection. However, in the interest of cooperation, a substitute appendix (ix) is attached, which lists the reference to Schreiner et al. This new appendix (ix) may be substituted for previous appendix (ix) if necessary.

Conclusion

For the reasons as stated in the Appeal Brief, and also as stated above, the appellants request that the Examiner's rejection of the claims be reversed.

Respectfully submitted,

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IX – EVIDENCE APPENDIX

Schreiner et al.	PG Pub	US 2002/0175591 A1	Published Nov. 28, 2002

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(54) PROCESS FOR THE MANUFACTURE OF PIEZOCERAMIC MULTILAYER ACTUATORS

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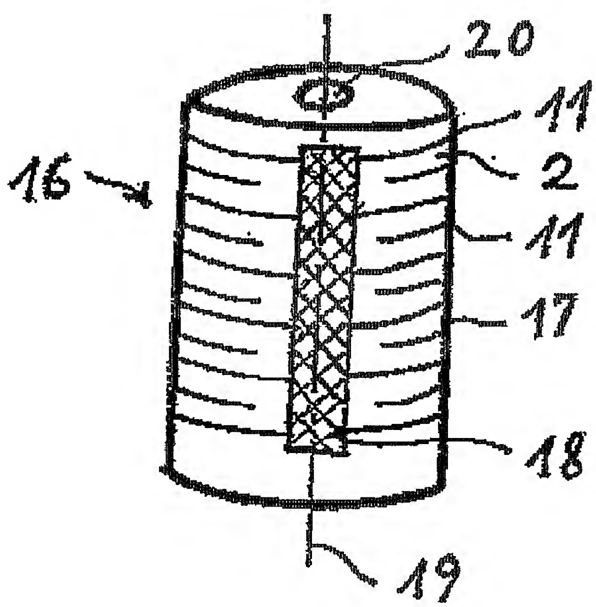
(57) ABSTRACT

For the manufacture of multilayer actuators, the laminate is split into several actuators, which are pyrolized and then sintered. Because lamination in the unsintered body often produces non-homogeneity in the density, and the shrinkage during the firing of the ceramic is not of a constant value, the final geometry of the actuators can only be accurately obtained by the hardening of the sintered actuators. But in this case the internal electrode layers deposited in the actuators are thereby also processed, which can cause electrical flashovers and leakage currents during operation.

Thus, according to the invention, a procedure is provided in which the block of the stacked green films provided with internal electrodes is laminated, that at least one actuator is separated from the block, that the actuator obtains its shape by means of a machining operation, that it is then sintered, that the sinter skin produced by the sintering is used as an insulating layer and that the sinter skin is abraded at the points where the internal electrodes are connected to the external electrodes.



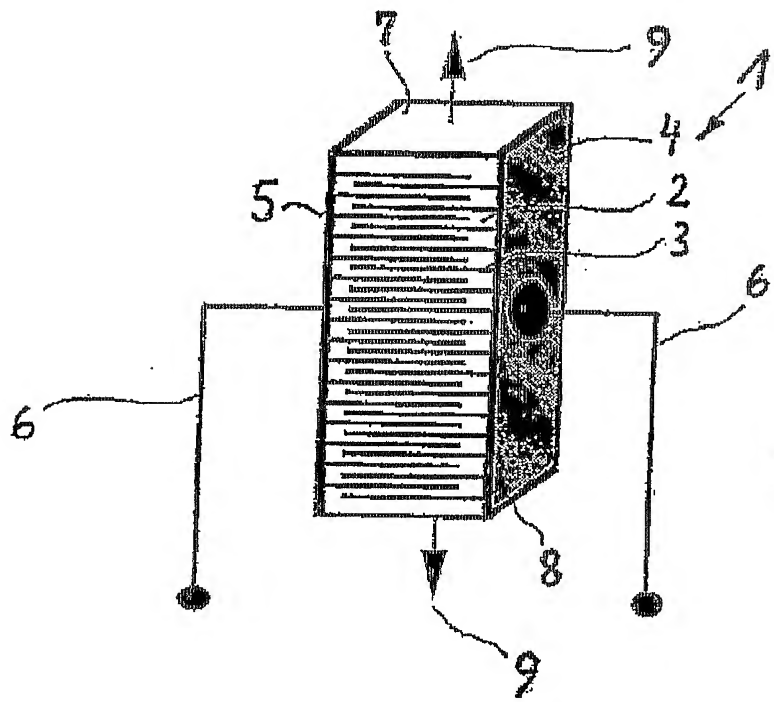


Fig. 1

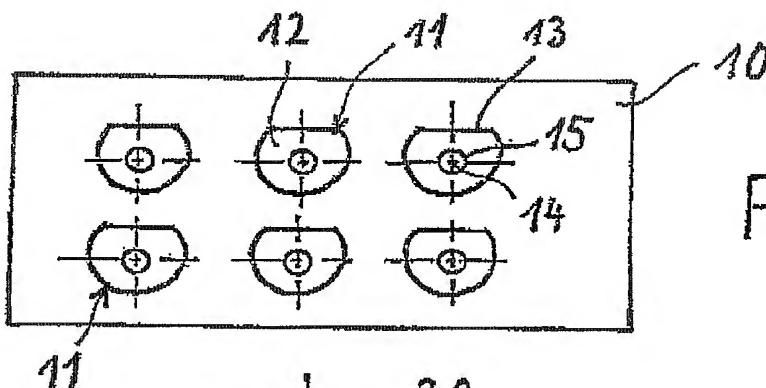


Fig. 2

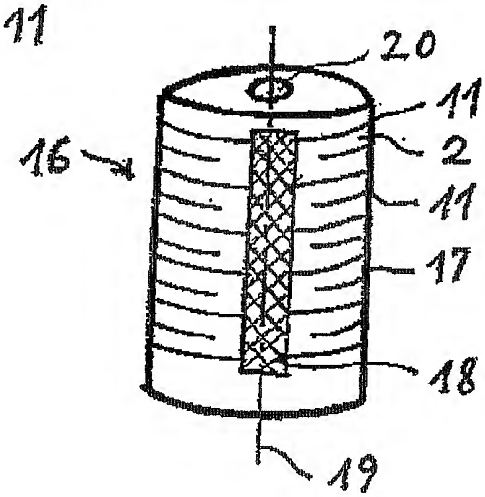


Fig. 3

PROCESS FOR THE MANUFACTURE OF PIEZOCERAMIC MULTILAYER ACTUATORS

[0001] The invention concerns a process for the manufacture of piezoceramic multilayer actuators according to the preamble of the first claim.

[0002] A piezoceramic multilayer actuator 1 is shown schematically in **FIG. 1**. The actuator consists of stacked thin layers 2 of piezoelectrically active material, for example lead zirconate titanate (PZT), with conductive internal electrodes 3, which are led out alternately to the surface of the actuator, disposed between said layers. External electrodes 4, 5 interconnect the internal electrodes 3. As a result, the internal electrodes 3 are electrically connected in parallel and combined into two groups. The two external electrodes 4, 5 are the connecting poles of the actuator 1. They are connected via the connections 6 to a voltage source, not shown here. If an electrical voltage is applied via the connections 6 to the external electrodes 4, 5, this electrical voltage is transmitted in parallel to all internal electrodes 3 and produces an electric field in all layers 2 of the active material, which is consequently mechanically deformed. The sum of all of these mechanical deformations is available at the end faces of the head region 7 and the foot region 8 of the actuator 1 as a useable expansion 9 and/or force.

[0003] Piezoceramic multilayer actuators are fabricated according to the prior art as monoliths, that is to say the active material onto which internal electrodes are deposited by a silk screen process prior to sintering, is disposed as a so-called green film in successive layers as a stack that is compressed into a green body. The compression of the green body is usually carried out by lamination under the action of pressure and temperature in laminating moulds. Depending on the lamination tool used, this process determines to a large extent the external shape of the actuators. The laminate is separated into several actuators, which are pyrolized and then sintered. Since lamination in the unsintered body often produces non-homogeneity in the density, and the shrinkage during the firing of the ceramic is not of a constant value, the final required geometry of the actuators can only be accurately obtained by the hardening of the sintered actuators. However, in this case the internal electrode layers deposited in the actuators are thereby also processed. If the processed surfaces are not subsequently electrically insulated, then when these piezoceramic multilayer actuators are actively operated, there is a risk of an electrical flashover at the actuator surface because the dielectric field strength in air, which amounts to approximately 1000 V/mm, is exceeded by the operating field strengths of over 2000 V/mm. At the same time the smearing of the electrodes caused by the hardening additionally leads to reduced dielectric strength and/or leakage currents.

[0004] The object of the present invention is to present a process that simplifies the manufacture of multilayer actuators and by which the demonstrated disadvantages are avoided.

[0005] This object is achieved by means of the characterising features of the first claim. Advantageous developments of the invention are claimed in the sub-claims.

[0006] By stacking green films made of piezoceramic material, which are printed with the corresponding patterns of the internal electrodes for at least one piezoceramic multilayer actuator and by corresponding lamination under pressure of around 100 bar at a temperature of approximately 120° C., a green body is obtained with high mechanical strength, good adhesion between film layers, good mechanical machinability and homogeneous density. According to the invention, it is therefore possible to easily detach the multilayer actuators from such a green body as a laminate and subsequently by machining to yield their shape, which is usually already the final shape, so that after sintering the actuators require no further finishing. The insulating sinter skin needs only to be removed at the connecting faces where the internal electrodes have to be connected to the respective external electrode, for example by grinding. Due to the high mechanical strength of the laminate blocks, all machining operations, such as turning, milling, sawing, drilling or grinding are possible. In this case the bodies are neither damaged nor deformed. Due to the lower hardness of the material compared to the sintered state, tool wear is considerably reduced, thus making low-cost production possible.

[0007] Due to sintering, a so-called sinter skin forms all over the surface of the piezoceramic multilayer actuator, which sinter skin has such a high electrical insulating capability, even in the region where the internal electrodes emerge at the surface of the actuator, that subsequent insulation of the surfaces of the piezoceramic multilayer actuator can usually be omitted.

[0008] Through suitable choice and/or combination of machining methods, the good machinability of the laminate enables piezoceramic multilayer actuators to be manufactured with different shapes. The cross-sectional areas can be circular, elliptical, square or polygonal. All edges of the green bodies can be broken, chamfered or rounded off prior to sintering. The ease of machining of the ceramic material in the green phase also enables rotationally symmetric mouldings to be produced.

[0009] The laminated block with the at least one multilayer actuator has a high strength and a high dimensional stability. It is thus possible, prior to sintering, to place several boreholes or pocket holes in the block and/or the unsintered piezoceramic multilayer actuator, which can additionally be provided with a thread. Such an arrangement can be advantageous for subsequent applications, such as fixings or connections. Since the layers of the internal electrodes are penetrated by the boreholes or pocket holes as well as by the mahine-cut thread, in this case the sinter skin produced by sintering can also be advantageously used as an insulating layer.

[0010] A further option for shaping the multilayer actuators consists in punching holes of the required size, shape and number in the green films in the same operating cycle, prior to lamination, in which the green films are suitably punched out for the laminating mould. The green films with the printed internal electrodes thereon are then stacked one on top of the other in the required number and arrangement, so that the boreholes or pocket holes are produced in the desired arrangement and depth. Here again, threads can be machine-cut in the holes following lamination.

[0011] To increase stability and to maintain dimensional accuracy, the boreholes, through-holes or pocket holes can be filled prior to lamination with a filler which prevents any plastic deformation of the recesses which otherwise may

occur during lamination. This filler is chosen so that under lamination conditions it is not more plastic or cannot be deformed to a greater degree than the piezoceramic material of the green films.

[0012] A filler may consist of a hard, dimensionally stable and, during lamination, thermally stable material, for example metal or ceramic. According to the shaping, pins or threaded pins can be inserted into the boreholes or pocket holes.

[0013] Furthermore, plastic or thermoplastic fillers, in particular a highly-flexible rubber or rubber-like plastic, are suitable. Here too the filler can have the form of a pin or threaded pin.

[0014] Following lamination, the pins or threaded pins are withdrawn or unscrewed from the laminate.

[0015] Fillers which remain dimensionally stable up to the lamination temperature are also suitable. During lamination or sintering these fillers smelt or pyrolize. For example, wax or low-melting-point polymers can be removed from the laminate by heating. A suitable organic material can also be used as a filler, such as is known from the prior art for forming porous ceramics, for example carbon black or a polymer that pyrolizes without residues during lamination or sintering at temperatures up to 700° C.

[0016] The thermal removal may also be achieved by melting out and/or thermal decomposition in a thermal process preceding sintering, for example an appropriate debonding process.

[0017] The invention is explained in further detail with the aid of an exemplifying embodiment in which:

[0018] **FIG. 2** shows a green film with several internal electrodes, and

[0019] **FIG. 3** shows a multilayer actuator manufactured according to the process according to the invention.

[0020] **FIG. 2** shows a green film **10** made of piezoceramic material already punched out for the laminating mould. Six internal electrodes **11** are each placed on this green film, this application usually being achieved by the silk screen process. The assignment of several internal electrodes to one green film allows the efficient manufacture of several multilayer actuators at the same time. On one side of the circular cross-sectional area **12**, a circular section is cut out so that the area is limited by a secant **13**. A hole **15** is punched out concentrically to the mid-point **14**.

[0021] The required numbers of green films are stacked one above the other to form a block, so that the internal electrodes lie one above the other. The number of films depends on the size of the multilayer actuator. In the present exemplifying embodiment, the block has six multilayer actuators. Due to the ease of separation, following lamination, the multilayer actuators, still in the green state, are separated from each other around the internal electrodes. Likewise still in the green state, the final machining of the multilayer actuators can then take place until the specified basic diameter of the multilayer actuator is obtained. Only after this are the multilayer actuators sintered.

[0022] The arrangement of the internal electrodes **11** on the green film **10** always has the same orientation. These are internal electrodes of the same polarity. The internal electrodes of the opposite polarity can be fabricated in the same way. In this case, however, their orientation is opposite to the orientation of the internal electrodes of opposite polarity assigned to them, that is to say rotated by 180 degrees on the subsequent green film. The electrode layers with the opposite polarity therefore alternate. In a block which shows the contour of a multilayer actuator, the holes **15** lying one above the other form a continuous recess.

[0023] A multilayer actuator **16** that has been manufactured according to the process according to the invention is shown in a schematic, much enlarged representation in **FIG. 3**. It has a circular cross-section **12** and is fully coated by a sinter skin **17**. The internal electrodes **11** of the same polarity are fully exposed on the peripheral face, whereas in the case of the internal electrodes of opposite polarity the circumference is broken because of the missing circular section. This design is advantageously utilised to connect the internal electrodes of the same polarity to the respective external electrode **18**, at the opposite sides of the multilayer actuator where the internal electrodes of the same polarity can now be seen at the periphery. The sinter skin **17** is removed in this region by grinding, and the internal electrodes **11** are exposed at their peripheral face. A continuous recess **20**, formed from the holes **15** lying one above the other in the green films **10**, which can be used for fixing purposes, runs concentrically to the axis **19** of the multilayer actuator **16**.

1. Process for the manufacture of piezoelectric multilayer actuators, in which thin layers made from a piezoceramic material, termed green films, onto which at least one internal electrode is placed, are stacked one above the other into a block, so that the internal electrodes are led out alternately at opposing faces of the actuator, where they are interconnected by an external electrode, characterised in that the block is laminated, that at least one actuator is separated from this block, that the actuator obtains its shape by means of a machining operation, that it is then sintered, that the sinter skin produced by the sintering is used as an insulating layer and that the sinter skin is abraded at the points where the internal electrodes are connected to the external electrodes.

2. Process according to claim 1, characterised in that the shaping is achieved by machining.

3. Process according to claim 1 or 2, characterised in that multilayer actuators, which have square, polygonal, circular or elliptical cross-sectional areas, are produced by the shaping.

4. Process according to claim 1 or 2, characterised in that rotationally symmetric multilayer actuators are produced by the shaping.

5. Process according to one of claims 1 to 4, characterised in that one or more through-holes or pocket holes are introduced into the laminated block of at least one multilayer actuator.

6. Process according to one of claims 1 to 4, characterised in that prior to lamination, holes of the required size, shape and number are punched in the green films and the green films provided with the internal electrodes are then stacked one on top of the other in the required number and arrangement, so that the boreholes or pocket holes are produced in the desired arrangement and depth.

7. Process according to one of claims 5 or 6, characterised in that a thread is machine-cut in the boreholes or in the pocket holes, respectively.

8. Process according to one of claims 5 to 7, characterised in that to increase stability and to maintain dimensional accuracy, the borehole or the pocket holes in the multilayer actuators can be filled prior to lamination with a filler.

9. Process according to claim 8, characterised in that a hard, dimensionally stable and, during lamination, thermally stable material, is used as a filler.

10. Process according to claim 8 or **9**, characterised in that a filler made from metal or ceramic or another hard, dimensionally stable and, during lamination, thermally stable, material is used.

11. Process according to claim 8, characterised in that a plastic or thermoplastic material is used as a filler.

12. Process according to claim 11, characterised in that a highly-flexible rubber or a rubber-like plastic is used.

13. Process according to one of claims 8 to 12, characterised in that the filler is used in the form of pins or threaded pins.

14. Process according to claim 13, characterised in that following lamination, the pins or threaded pins are withdrawn or unscrewed from the laminate.

15. Process according to claim 8, characterised in that a filler is used that remains dimensionally stable approximately up to the lamination temperature and is thermally removed.

16. Process according to claim 15, characterised in that a wax or a low-melting-point polymer is used as a filler, and that these fillers smelt during lamination or sintering.

17. Process according to claim 15, characterised in that a suitable organic material that pyrolizes without residues during lamination or sintering is used as a filler.

18. Process according to claim 15, characterised in that the thermal removal is achieved by smelting and/or thermal decomposition in a thermal process preceding sintering, for example an appropriate debonding process.

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